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TRANSLATION

INVESTIGATING FINNED DIFFUSORS

By

V. K. Migay

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

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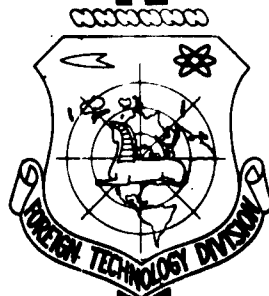
UNEDITED ROUGH DRAFT TRANSLATION

INVESTIGATING FINNED DIFFUSORS

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Investigating Finned Diffusors

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Presented are results of experimentally investigating the effect of various geometric parameters on the effectiveness of a finned diffusor.

In [L.1,2] was introduced a new method of raising the effectiveness of diffusors with greater angle of opening by placing a special transverse fin arrangement on its walls. The intensive macro separation of the flow is replaced in this case by a system of small separations, which, as was shown by numerous experiments, leads to a sharp increase in the effectiveness of the installation. No doubt there is practical interest in studying the effect of the angle of expansion , parameters of finned system, form of diffusor and, especially, annular finned diffusors, in connection with the possibility of employing these diffusors in turbo-machines. The investigations were made on an air installation (fig.1). All diffusors had identical length $1 = 195$ mm and identical diameter at input $d_1 = 100$ mm. The field coefficient at input into the diffusor $w_{cp}/w_{max} \simeq 0.95$. Static pressure at input into the diffusor was determined in the section, corresponding to minimum static pressure along the length of the cylindrical part, equalling $2d_1$. Atmospheric pressure was accepted as counter pressure. Investigated were round and annular diffusors with full angle of cone opening $\beta = 22, 31, 40, 60°$, smooth and finned respectively. Annular diffusors were formed by means of cylindrical round inserts $d = 40, 60$ mm, which were centered by rings with three streamlined radial fins, placed at an angle of $120°$ with respect to each other. Diffusors were made of Silumin. Depth of bored grooves $e = 7$mm, width $b = 3$ mm, thickness of ribs $t = 1.5$ mm. The first inter-fin hollow was made at a distance of 3 mm from input edge. Each finned

diffusor had 11 grooves. The effectiveness of the diffusors was evaluated by the efficiency value

$$\eta = \frac{p_{cr,2} - p_{cr,1}}{p/2\,(w_1^2 - w_2^2)}.\qquad 1$$

thoroughness of impact

$$\varphi = (1-\eta)\frac{n+1}{n-1}\qquad 2$$

(n - degree of diffusor expansion) and resistance coefficient

$$\xi = \frac{p_2 - p_1}{\rho\frac{w_1^2}{2}}.\qquad 3$$

The dependence of value η upon the Re number or upon the rate at input into the diffusor w_1 for finned diffusors with $\beta = $ 22, 31, 40 and 60° had the very same nature as for smooth ones, with exception of case $\beta = $ 31° (fig.2). For all diffusors in this case was observed a minimum for η at w_1 50-60 m/sec.
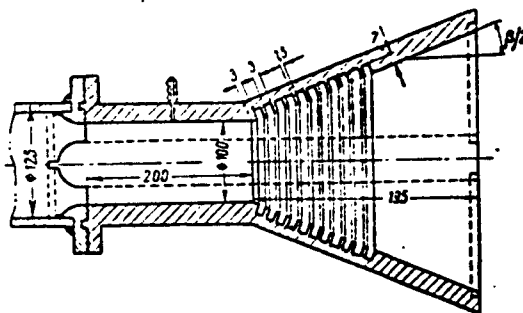

Fig.1. Schematic of experimental installation

We want to point out, that the value $\eta_{min}/\eta \leq 0.09$, i.e. reduction of η is small. The presence of a minimum should be explained by possible origination at these velocities of periodic phenomena (acoustic irradiation of inter-fin hollows), which, as shown by special experiments, do somewhat reduce the effect.

The mentioned acoustic irradiation originates as result of resonance, when the frequency of separation of eddies from the ends of the ribs and the natural oscillation frequency of air volumes in the inter-fin hollows coincide. By selecting the geometry of grooves it is possible to attain elimination of these effects. This problem requires

further elucidation.

In fig.3 are given data for the case β = 40°, in fig.4 is given the dependence of the efficiency ratio of finned diffusors respectively the dependence of efficiency of smooth diffusors upon the angle β. As is evident from the graphs, the value of η_{ad}/η_{smooth} has a maximum at $\beta \approx 40-45°$. In this case η_{or} rise by 2.2 - 2.4 times in comparison with smooth diffusor (lower $_{or}$ = finned). When $\beta > 40-45°$ the value η_{fin}/η_{smooth} decreases. As was shown by [2] the necessary condition for positive effect of transverse ribbing (fins) is the fact, that the first groove should be placed in the nonseparating zone. At greater opening angles ($\beta \approx 60°$) the flow separates at the input section of the diffusor and no active flow is directed around the ribs (fins).

For the case where β=60° were carried out special investigations on the profiling of the input edge of the diffusor.
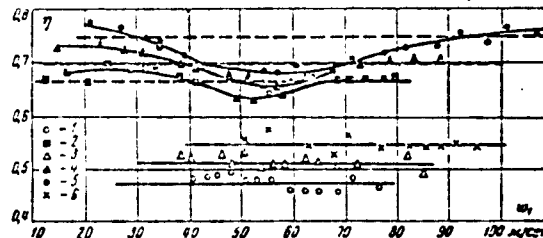

Fig.2. Effectiveness of diffusor with β= 31°

1-round smooth diffusor n = F_2/F_1 = 4; φ =0.875; xi = 0.44; 2-round finned diffusor n = 4; φ= 0.558; xi=0.616; 3- annular smooth diffusor n=4.57; φ= 0.765; d_2/d_1 = 40/100; xi= 0.485; 4- annular finned diffusor n = 4.57; φ= 0.468; d_2/d_1 = 40/100; xi=0.666; 5- annular finned diffusor n=5.7; φ= 0.356; d_2/d_1 = 0.6; xi=0.73; 6-annular smooth diffusor n = 5.7; φ =0.65; d_2/d_1 = 0.6; xi = 0.528.

The input edge was made with various larger curvature radii, position of the first interfin hollow varied all the way up to the point of making same directly on the input edge. But all these measures led to no origination of the effect; the efficiency of a finned diffusor in all instances was equal to the efficiency of the smooth diffusor. In this way, the use of finned diffusors for $\beta > 55-60°$ is not rational. The mentioned conclusion is valid only for diffusors without support, for the

latter the upper limit for β is displaced in direction of greater β. In the zone of $60°$ $>\beta>40°$ no experimental points have been obtained. It should be assumed that in the section of this zone ($\beta < 60°$) the movement in the finned diffusor will be unstable.

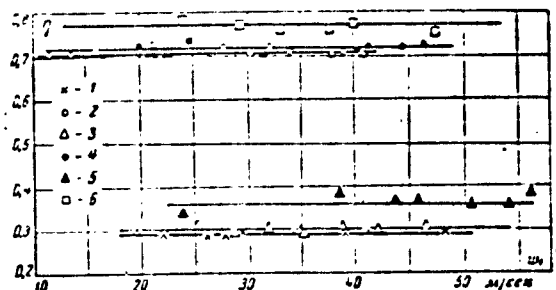Fig.3.Effectiveness of diffusor with $\beta = 40°$.

1-round smooth diffusor n = 5.85; φ = 1; xi=0.26; 2-round finned diffusor n=5.85; φ = 0.424; xi = 0.67; 3-annular smooth diffusor n = 6.85; φ = 0.94; d_2/d_1 = 0.4; xi= 0.294; 4-annular finned diffusor n= 6.85;φ= 0.382; d_2/d_1 = 0.4; xi=0.7. 5-annular smooth diffusor n=8.68; φ = 0.814; d_2/d_1 = 0.6; xi=0.35; 6-annular finned diffusor n=8.68; φ= 0.296; d_2/d_1 = 0.6; xi = 0.755.

Transverse ribbing is effective in this case, when there is considerable flow separation and reverse currents, whereby the more intensive these phenomena (to the above mentioned maximum) the higher is the effectiveness of finned diffusor. When the flow is directed around a finned system in the inter-rib hollows are observed regular eddies, for the formation of which is consumed a specific part of energy of the basic stream. When $\beta \approx 40-50°$ this energy is of one order. With a decrease in β ($\beta < 40-50°$) the intensity of separation in the smooth diffusor is relatively decreased and consequently, the favorable effect of transverse finning, eliminating macro separation of the flow and creating additional losses, on the formation of regular eddies and microseparations,decreases. This explains the drop in value η_{fin}/η_{sm} with the reduction in β($\beta < 40-50°$).

When $\beta \approx 20°$ the losses, connected with macroseparation and during flow around the ribs, become approximately identical and the ribbing in this case from the view point of efficiency is practically ineffective. The dotted curve in fig.4 represents data for round finned diffusors converted into the value of impact completeness φ.

As is known, the value φ depends weakly upon the degree of expansion n (especially at small n) and this curve appears to be universal for round diffusors.

Fig.5 contains data, obtained for round finned diffusors, comparable with known experiments by Gipson[L.8]and Peters[L.4] for smooth round diffusors.
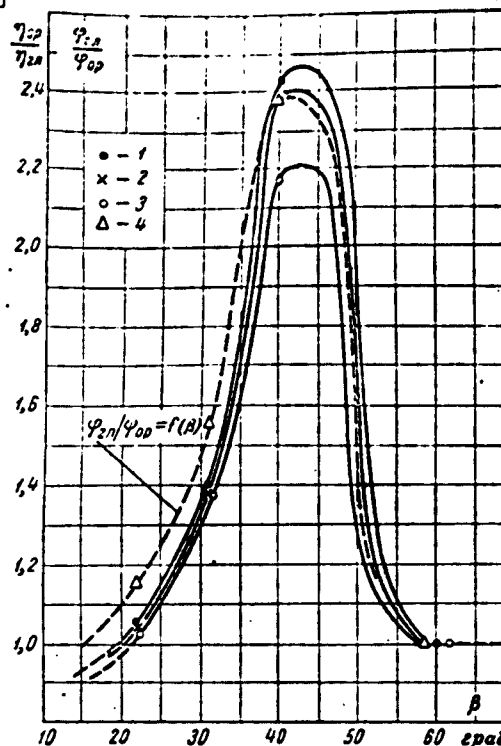
Fig.4.Dependence of diffusor effectiveness upon angle of expansionβ.
1-round diffusor; 2-annular; $d_2/d_1 = 0.4$; 3- annular; $d_2/d_1 = 0.6$; 4-round diffusor;
$\varphi_{sm}/\varphi_{fin} = f(\beta)$.

We want to point out that if the minimum for smooth diffusors is observed at $\beta \approx 6-8°$, then for finned diffusors it is displaced and in conformity with above mentioned circumstances it equals $\beta \approx 40°$ (slope of curve at $\beta < 20°$ is of no practical interest). In this way,it is most reasonable to use finned diffusors at greater opening angles - of the order of $40°$.

For annular diffusors, as is evident from data in fig.4.,the use of fins gives a relative approximate same effect, as for round ones. A certain slight reduction in the value η_{fin}/η_{sm} for the annular diffusor in comparison with the round one is con-

nected with the fact, that inserts reduce somewhat the intensity of flow separation in comparison with round diffusers, as result of which the relative effect of finning, eliminating macro-separation, decreases slightly. ·

In fig.6. are given velocity fields, measured by pneumometric tubes at the output from the annular diffusor in three sections,situated at an angle of 120° relative to each other. The velocities were determined by indications of absolute and static pressure tubes. It was established first, by studying silk threads, that the flow at the output moves continuously, which is confirmed by pneumometric measurements.
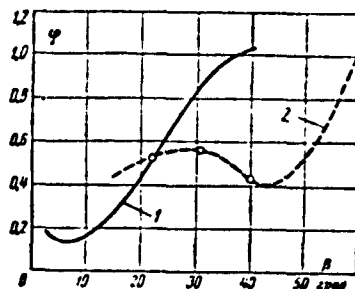
The velocity fields for smooth diffusors were not measured in connected with flow instability in these diffusors (nonstationary separation). In this way,transverse finning substantially improves the velocity profile at output from diffusor. This circumstance is of special importance. This is important,for example,when a radial diffusor is placed behind an axial one.

Fig.5.Dependence of the coefficient of impact completeness upon the angle of diffusor expansion.
1.according to Gibson [L.3] and Peters [L.4]
2-finned diffusors.

In a smooth diffusor at $\beta = 20°$ there are substantial flow separations and the field of velocities at the output from such a diffusor will have reverse currents. With respect to efficiency a finned diffusor with $\beta = 40°$ is equivalent to a smooth one with $\beta = 20°$ (fig.5), but the field of velocities at the output from a finned diffusor is more uniform. In cases where the uniformity of the velocity field directly at the output is of considerable value, the finned diffusor will have an additional advantage over the smooth diffusor with $\beta = 20°$, and it is possible, also in front of smooth diffusors with smaller angles of opening. Here is necessary to keep in mind, that the mentioned ribbing is effective only at continuous entry of the flow into the diffusor. In case of absence of such it is necessary to assure a definite stabilizing section at the input.

Unsolved remains the problem concerning the effect of flow twist at the input into a finned diffusor.

At the TSKTI was tested a greater number of finned diffusors of different types. [L.1] gave results of investigating diffusors of small dimensions (d_1=30 mm); in this report are given data for diffusors with d_1=100 mm. In this and in the other cases the effectiveness of the diffusor was approximately doubled. In this way it can be assumed, that the scale effect at least in the investigated zone at rational planning of fins, does not affect the effectiveness of finned system.
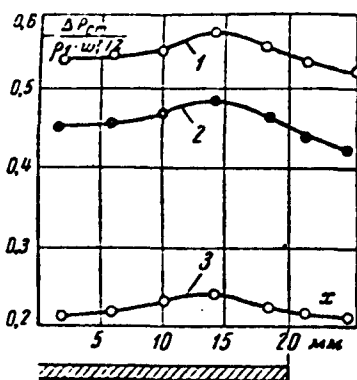

Fig.6. Velocity fields in an annular finned diffusor (β = 40°; d_2/d_1 = 0.6, w_1= 50 m/sec.

The effect of fin height (depth of groove) width of groove and number of ribs was investigated for the convenience of the experiment on a plane model of a diffusor with one-sided expansion (input 90X70 mm), output 180X70 mm, angle of opening one of the sides 21°; the second wall was straight.) The effectiveness of the diffusors was evaluated by the value η. The experimental results are listed in table, where data are presented by the η fin/η_{an} ratio. The effect of groove depth a

Fig.7. Pressure distribution in inter-fin hollows:
1-4-th groove; 2-6-th groove;3-14-th groo ve.

(height of rib) was investigated at a constant width of the groove b = 5 mm and at ten ribs with a thickness of 1.5 mm. The first inter-rib hollow is situated at a distance of 3 mm from input edge. The parameter a acquired values: 0.5; 1; 2;4;
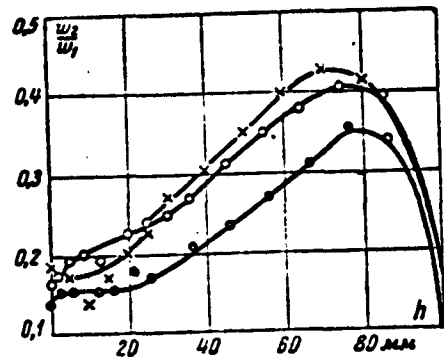
8; 10; 15; 20 mm. Small depths (a = 0.5 mm, 1 mm; a/b = 0.1; 0.25) lead to deteriora-
tion of the flow ($\eta_{fin}/\eta_m < 1$) and various types of surface roughnesses do likewise
intensify flow separation. For the origination of the effect a sufficient relative
depth of groove is necessary. At a/b = 2-2.5 the eddy system begins stabilizing, and the
effectiveness of the installation does not rise.

The positive effect originates in the case, when regular eddies are formed, for
which a definite groove depth is necessary.

In addition to visual observations [L.2] the presence of eddies was confirmed by
static pressure measurements, for which in the flat walls of the diffusor in points
corresponding to inter-rib hollows drainages are set up in height. In fig.7 are shown
pressure epures, obtained by the indications of these drainage units. As is evident
from the graphs, in the investigated grooves are observed pressure minimums, whereby on
the bottom of the groove the pressure is restored to the pressure in the flow. The
mentioned pressure minimums indicate the presence in inter-rib hollows of intensive
eddy formations. The mentioned circumstances indicate, that the pressure in an ordi-
nary drainage opening is nonstant in height, as it was ordinarily assumed. In drainages,
as shown by visual observations [L.5] are also observed eddies. But the presence of eddy
does not distort the indication of the drainages, because the pressure on the bottom
of the opening or past the eddy down in depth is restored to the pressure in the flow.
The effect of groove width b was investigated at maximum depth a=20 mm for the purpose
to possibly eliminate the influence of the value a. The parameter b acquires a value
1; 3; 5; 8; 16 mm. In experiments for each case was assured a sufficiently large num-
ber of ribs, because a further increase in their number did not change the result
(see table). Practically there is no special difference at b = 1;3;5 in the effecti-
veness of the diffusor and the value b in this range should be selected from technologi-
cal considerations. When b > 5 the effect disappears, apparently, because of increased
resistance when flow is directed around such a system of ribs(fins).

Table

τ_{op}/τ_{rz}	1	0.857	0.915	1.25	1.46	1.54	1.65	1.71	1.71
a, mm	0	0.5	1	2	4	8	10	15	20
a/b	0	0.1	0.25	0.4	0.8	1.6	2	3	4

Effect of parameter b (a= 20 mm)

τ_{op}/τ_{rz}	1.64		1.71		1.71		не устой. unstable		0.5	
b, mm	1		3		5				16	

Effect of number of grooves n (b=1 mm, a=20 mm)

τ_{op}/τ_{rz}	1.06	1.14	1.29	1.4	1.54	1.57	1.63	1.64	1.64
n	1	3	5	7	9	11	13	15	40

Effect of number of grooves n (b = 3 mm, a = 20 mm)

τ_{op}/τ_{rz}	1.04	1.13	1.3	1.515	1.63	1.68	1.71	1.71	1.71
n	1	2	3	4	5	6	7	10	15

Effect of number of grooves n (b = 5 mm, a = 20 mm)

τ_{op}/τ_{rz}	0.6	0.7	0.75	1.5	1.64	1.71	1.71
n	1	2	3	4	5	6	20

In the table are also given data on the effect of the number if ribs on the effectiveness of a finned diffusor. To obtain the effect it is necessary to make a small number of grooves.   at b=1 mm are required 13 ribs, at b = 3 mm seven ribs, at b = 5 mm six ribs . A further increase in ribs does not increase the effectiveness of the diffusor.

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